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(54) Title: IMMUNOSTIMULATORY COMPOSITIONS AND USES THEREOF

(57) Abstract: The present invention provides novel immuno-stimulatory polypeptides, and methods for their use and identification.

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Immunostimulatory Compositions and Uses Thereof

Cross Reference

This application claims the benefit of U.S. Provisional Patent Application No. 60/633,825 filed December 7, 2004, which is hereby incorporated by reference in its entirety.

Field of the Invention

The invention relates to the fields of polypeptides, therapeutics, and immune system activation.

Background

Phagocytes such as macrophages and neutrophils provide a primary line of defense against a variety of diseases, including those caused by infectious agents and cancers (Gomme and Bertolini, 2004). During a study of the role of inflammation in development of immunity, Yamamoto and Homma (1991) discovered that a serum protein was required to activate macrophages. This protein is the vitamin D-binding protein (DBP). The human protein is known as group-specific component, or Gc protein. DBP is an abundant, multifunctional, polymorphic glycoprotein in human serum. Highly conserved homologs of this protein occur among all mammalian species (Yang et al., 1990; White and Cooke, 2000). As its name implies, one role of the protein is as a vehicle for circulating vitamin D in blood. Another function involves binding of actin released into the blood during tissue injury. The glycan of the serum protein can be processed to a potent anti-cancer agent, which is expressed through its macrophage activation and anti-angiogenesis activities (Kanda et al., 2002; Gomme and Bertolini, 2004).

DBP is a 458-amino acid protein in humans and consists of three major domains similar to albumin (Head et al., 2002; Otterbein et al., 2002; Verboven et al., 2002). DBP is a glycoprotein that carries a single trisaccharide group (Yang et al., 1985; Cooke and David, 1985). The O-linked glycan is found in the carboxy-terminal Domain III, attached to the hydroxyl group of a specific threonine residue (Thr420 in protein from human). Its structure has been determined as NeuNAc(α2$\rightarrow$3) Gal(β1$\rightarrow$3) GalNAc(α1$\rightarrow$O) Thr, with

significant amounts of the O-glycan found only on the Gc1 isoform (Coppenhaver et al., 1983; Viau et al., 1983). Some of the glycans contain a second NeuNAc linked α2→6 to GalNAc. Extensive work by Yamamoto and colleagues (Yamamoto and Kumashiro, 1993; Yamamoto and Naraparaju, 1996 a,b) suggested that DBP has remarkable therapeutic value as an activator of macrophages. Its potent stimulatory activity for macrophage phagocytosis is expressed when its glycosylated site is processed to a single O-linked GalNAc by removal of the NeuNAc (sialic acid) and the Gal residues (Yamamoto and Homma, 1991; Yamamoto and Kumashiro, 1993). The precursor protein can be processed to the active form *in vitro* by treatment with immobilized sialidase and ß-galactosidase (Yamamoto and Kumashiro, 1993; Yamamoto and Naraparaju, 1998). In animals, the modified protein is referred to as DBP-MAF, whereas the active form of the human protein is known as Gc-MAF. These designations are used interchangeably. The active form of the protein reduces tumor cell load (Kisker et al., 2003; Onizuka et al., 2004), provides a therapy against viral infections such as HIV (Yamamoto et al., 1995), and promotes bone growth (Schneider et al., 1995; 2003) and therapy against bone disorders such as ostepetrosis (Yamamoto et al., 1996b). DBP-MAF has also been found to be an effective anti-angiogenesis factor (Kanda et al., 2002; Kisker et al., 2003) and is a potent adjuvant for immunizations (Yamamoto and Naraparaju, 1998). A lectin receptor that specifically binds GalNAc residues was identified on the surface of human macrophages (Iida et al., 1999).

Cancer cells secrete, and some virus particles carry on their surface, an enzymatic activity (N-acetylgalactosaminidase) that depletes the precursor protein in the serum by removing the O-glycoside, which renders the protein inactive as a macrophage activating factor (Yamamoto et al., 1996a, 1997). A decrease in active Gc-MAF may be a major factor in progression of disease. Introduction of the *in vitro* processed protein leads to dramatic reduction in the amount of cancer cells in animals (Yamamoto and Naraparaju, 1997; Kanda et al., 2002; Kisker et al., 2003; Onizuka et al., 2004) and appears to also reduce the number of HIV particles in infected individuals (Yamamoto et al., 1995). This conclusion is based largely on the decrease in activity of N-acetylgalactosaminidase, whose level appears to be directly correlated with tumor and viral loads in cancer and in HIV-infected patients, respectively (Yamamoto et al., 1997).

Summary of the Invention

The present invention provides novel immuno-stimulatory polypeptides, and methods for their use and identification. In one aspect, the present invention provides a substantially purified polypeptide comprising an amino acid sequence according to formula 1:

B1-[X1-S-T-X2-P-P-S]-B2;

wherein X1 is selected from the group consisting of P and S; and

X2 is selected from the group consisting of P, S, and T; and

wherein B1 and B2 are independently 1-5 amino acid residues, or are absent.

In a second aspect, the present invention provides a substantially purified polypeptide comprising an amino acid sequence according to formula 2:

B1-[S-P-L-X1-S-X2-P]-B2;

wherein X1 is selected from the group consisting of L, T, and S; and

X2 is selected from the group consisting of A, N, P, T, and V; and

wherein B1 and B2 are independently 1-5 amino acid residues, or are absent.

In a third aspect, the present invention provides a polypeptide comprising an amino acid sequence of a polypeptide according to formula 3:

B1-[X1]-B2;

wherein X1 is a polypeptide selected from the group consisting of **SEQ ID NOS:1-149**; and

wherein B1 and B2 are independently 1-5 amino acid residues, or are absent.

In a fourth aspect, the present invention provides substantially purified compounds that compete with one or more of the polypeptides according to **SEQ ID NOS:1-149** for binding to a GalNAc-specific binding protein, such as GalNAc-specific lectin.

In a fifth aspect, the present invention provides pharmaceutical compositions comprising the substantially purified polypeptides of the invention and a pharmaceutically acceptable carrier.

In further aspects, the present invention provides a purified nucleic acid composition comprising a nucleic acid sequence that encodes a polypeptide according to

the invention, expression vectors comprising the purified nucleic acid, and host cells transfected with the expression vectors.

In a further aspect, the present invention provides methods for stimulating immune system activity in a subject, comprising administering to a subject an amount effective of a polypeptide of the invention for stimulating immune system activity.

In a further embodiment, the present invention provides methods for treating a subject with a disorder selected from the group consisting of infections, tumors, bone disorders, immune-suppressed conditions, pain, and angiogenesis-mediated disorders, comprising administering to the subject an amount effective of a polypeptide of the invention.

In a further embodiment, the present invention provides an improved method of vaccination in a subject, comprising administering to a subject receiving a vaccination an amount effective of a polypeptide of the invention for promoting an improved immune system response to the vaccination.

In a further aspect, the present invention provides a method for identifying a GalNAc mimetic compounds, comprising:

a) contacting a plurality of test compounds with a GalNAc-specific lectin under conditions to promote binding of the GalNAc-specific lectin with a GalNAc mimetic compound;

b) removing unbound test compounds;

c) repeating steps (a) and (b) a desired number of times;

d) contacting test compounds bound to the GalNAc-specific lectin with an amount effective of a polypeptide comprising of an amino acid sequence according to **SEQ ID NOS:1-149** to displace the bound test compounds if the bound test compounds are acting as GalNAc-mimetics; and

e) identifying those test compounds that are displaced from the GalNAc-specific lectin by a polypeptide comprising of an amino acid sequence according to **SEQ ID NOS:1-149**, wherein such test compounds are GalNAc-mimetic compounds.

Brief Description of the Figures

Figure 1 is a flowchart describing the algorithm used to search for patterns among the GalNAC mimetic polypeptides.

Detailed Description of the Invention

Within this application, unless otherwise stated, the techniques utilized may be found in any of several well-known references such as: *Molecular Cloning: A Laboratory Manual* (Sambrook, et al., 1989. Cold Spring Harbor Laboratory Press), *Gene Expression Technology* (Methods in Enzymology, Vol. 185, edited by D. Goeddel, 1991. Academic Press, San Diego, CA), "Guide to Protein Purification" in *Methods in Enzymology* (M.P. Deutshcer, ed., 1990. Academic Press, Inc.); *PCR Protocols: A Guide to Methods and Applications* (Innis, et al. 1990. Academic Press, San Diego, CA), *Culture of Animal Cells: A Manual of Basic Technique, 2nd Ed.* (R.I. Freshney. 1987. Liss, Inc. New York, NY), and *Gene Transfer and Expression Protocols*, pp. 109-128, E.J. Murray, ed. (1991). The Humana Press Inc., Clifton, N.J.).

The single letter designation for amino acids is used predominately herein. As is well known by one of skill in the art, such single letter designations are as follows:

A is alanine; C is cysteine; D is aspartic acid; E is glutamic acid; F is phenylalanine; G is glycine; H is histidine; I is isoleucine; K is lysine; L is leucine; M is methionine; N is asparagine; P is proline; Q is glutamine; R is arginine; S is serine; T is threonine; V is valine; W is tryptophan; and Y is tyrosine.

As used herein, the singular forms "a", "an" and "the" include plural referents unless the context clearly dictates otherwise. For example, reference to a "polypeptide" means one or more polypeptides.

The inventors have identified a series of polypeptide mimetics of GalNAc, using methods described herein. Using similar methods, the inventors previously identified the polypeptide mimetics of GalNAc disclosed in WO05/087793.

Such mimetics act as immunostimulatory compounds and can be used for the various methods of the invention described below. Thus, in a first aspect, the present invention provides a substantially purified polypeptide with an amino acid sequence comprising or consisting of an amino acid sequence according to formula 1:

B1-[X1-S-T-X2-P-P-S]-B2;

wherein X1 is selected from the group consisting of P and S; and

X2 is selected from the group consisting of P, S, and T; and

wherein B1 and B2 are independently 1-5 amino acid residues, or are absent,

or functional equivalents thereof.

In various preferred embodiments, X1 is P and X2 is P; X1 is P and X2 is S, X1 is P and X2 is T, X1 is S and X2 is P, X1 is S and X2 is S, or X1 is S and X2 is T.

In a second aspect, the present invention provides a substantially purified polypeptide comprising or consisting of an amino acid sequence according to formula 2:

B1-[S-P-L-X1-S-X2-P]-B2;

wherein X1 is selected from the group consisting of L, T, and S; and

X2 is selected from the group consisting of A, N, P, T, and V; and

wherein B1 and B2 are independently 1-5 amino acid residues, or are absent,

or functional equivalents thereof.

In various preferred embodiments, X1 is L and X2 is A; X1 is L and X2 is N; X1 is L and X2 is P; X1 is L and X2 is T; X1 is L and X2 is V; X1 is T and X2 is A; X1 is T and X2 is N; X1 is T and X2 is P; X1 is T and X2 is T; X1 is T and X2 is V; X1 is S and X2 is A; X1 is S and X2 is N; X1 is S and X2 is P; X1 is S and X2 is T; or X1 is S and X2 is V.

In a third aspect, the present invention provides a polypeptide comprising an amino acid sequence of a polypeptide according to formula 3:

B1-[X1]-B2;

wherein X1 is a polypeptide selected from the group consisting of **SEQ ID NOS:1-149**; and

wherein B1 and B2 are independently 1-5 amino acid residues, or are absent.

Each of the polypeptides according to SEQ ID NOS. 1-149 have been verified as GalNAc mimetics based on their identification in the screening assays described below, and thus can be used as immunostimulatory compounds and for the various methods of the invention described below. Alternatively, X1 can comprise or consist of any of the 2-mers, 3-mers, or 4-mer peptides disclosed herein in Tables 2 and 3.

In each of the first through third aspects of the invention, the B1 and B2 groups are optionally present, for example, to provide appropriate spacing for branched embodiments of the polypeptides, as described below.

In a fourth aspect, the present invention provides substantially purified compounds that compete with one or more of the polypeptides according to **SEQ ID NOS:1-149** for binding to a GalNAc-specific binding protein, such as GalNAc-specific lectin.

Such GalNAc-specific lectins include those purified from *Helix pomatia*, *Vicia villosa,* or *Robinia pseudoacacia,* or functional equivalents thereof (commercially available, for example, from Sigma Chemical Co., St. Louis, MO). Additional GalNAc-specific lectins include but are not limited to the following: Bauhinia Purpurea Lectin (BPL), Dolichos Biflorus Lectin (DBA), Griffonia Simplicifolia Lectin (GSL I - isolectin B4), Maculura Pomifera Lectin (MPL), Psophocarcpus Tetragonolobus Lectin (PTL), Ricinus Communis Agglutnin (RCA) I 120 and II 60, Saphora Japonica Agglutnin (SJA), Soybean Agglutnin (SBA), Wisteria Floribunda Agglutinin (WFA). Additional commercial sources of these lectins include the following: Alexis Platform, Reacto Labs, USBiological, Vector Labs, Molecular Probes, Biotrend, Chemikalien GmbH, Invitrogen Corp., Seikaguku America, EY Laboratories, Calbiochem, AlerCheck, Pierce, Accurate Chemical and Scientific Corp., MoBiTec, GALAB, Merck Biosciences, UK, Gentaur France, Biomeda, and Honen Corp, Japan.

The crystal structure of GalNAc-specific lectins from *Robinia pseudoacacia* (Rabijns et al., 2001) and from *Vivia villosa* were published (Babino et al., 2003). These structures are examples of the highly conserved sugar-binding sites of plant lectins (Loris et al., 1998). The critical amino acids in the polypeptide segments that form the carbohydrate-binding site are highly conserved among plant lectins, including those specific for GalNAc or Gal (Osinaga et al., 1997). As an example, the GalNAc-specific binding site in the *Vicia villosa* lectin is formed on the surface of the protein by four loops that contain the amino acids aspartate-85, glycine-103, tyrosine-127, asparagine-129, tryptophan-131 and leucine-213, which interact with functional groups on the sugar (Babino et al., 2003). A conserved aspartate-90 interacts with a divalent cation. Another GalNAc-specific lectin from *Robinia pseudoacacia* (black locust) has a binding site containing similar amino acid residues, e.g., aspartate-87, glycine-104. glycine-105, phenylalanine-129, asparagine-131, isoleucine-216 and aspartate-217 (Rabijns et al., 2001). A lectin that is highly specific for GalNAc, purified from the sea cucumber *Cucumaria echinata* and characterized (Sugawara et al., 2004), contains a similar group of amino acids such as glutamine-101, aspartate-103, tryptophan-105, glutamate-109,

arginine-115 and asparagine-123 that interact with the sugar. These amino acids are also found in the GalNAc-binding site of a rat hepatic lectin, RHL-1 (Kolatkar et al., 1998). Various lectins may contain bound divalent cations and are thus designated C-type lectins. A C-type lectin that is particularly important to this invention is a GalNAc – specific lectin on the surface of macrophages and dendritic cells (Suzuki et al., 1996; Iida et al., 1999; Denda-Nagai et al., 2002). (This class of proteins may or may not include specific divalent cations as part of their structure. Any protein, produced by any species or made synthetically, that binds GalNAc in a specific manner is appropriate for use in this technology.

Competition for binding of a polypeptide of the invention to GalNAc-specific lectins by a test compound can be determined by any suitable technique. For example, the GalNAc-specific lectin can be incubated first with a polypeptide of the invention, and then with the test compound. The test compound competes with the polypeptide of the invention if polypeptide binding to the GalNAc-specific lectin is 90% or less than its binding in the absence of the test compound, more preferably if polypeptide binding to the GalNAc-specific lectin is 80%, 70%, 60%, 50%, 40%, 30%, 20%, or 10% or less than its binding in the absence of the test compound. The desired level of competitive activity of a polypeptide of the invention can be selected for, as will be apparent to those of skill in the art. Similarly, as will be apparent to those of skill in the art, the GalNAc-specific lectin can be incubated first with the test compound, and then with the polypeptide of the invention and competition can be assayed as discussed above. Conditions should be suitable to promote binding, as described in the Examples below. Typically, physiological or near-physiological conditions are suitable for binding of a polypeptide of the invention to GalNAc-specific lectins, for example, room temperature in a buffer solution composed of 50 mM Tris-HCl, pH 7.5, containing 150 mM NaCl, 1 mM $CaCl_2$, 1 mM $MnCl_2$ and 1 mM $MgCl_2$. Polypeptides and the GalNAc-specific lectin can be used in these assays in any amount suitable for the specific assay conducted, preferably between 1 nM and 500 mM; more preferably between 10 nM and 500 mM, even more preferably between 100 nM and 100 mM.

Several variables can be modified to optimize binding to lectins: (1) Detergents are used to reduce nonspecific interactions. Stringency can be increased by increasing the concentration of detergents such as Tween-20, Triton X100, dodecyl maltoside, etc. (2)

Temperature can be varied between 4°C and 55°C. An increase in temperature may cause an increase or decrease in stringency, depending on the specific characteristics of the interaction. (3) The time of the binding step and the elution step can be adjusted to select for differences in the 'on' rates and 'off' rates. Because equilibrium factors apply to the interactions, complex formation can also be altered by concentrations of the reactants such as the target lectin. Displacement of polypeptides from the lectin by addition of test compound is also concentration dependent. These factors can be adjusted to provide optimal results.

The test compounds in this fourth aspect of the invention can comprise small molecules, nucleic acids, or polypeptides, such as those found in various commercially available compound libraries. In a preferred embodiment of this fourth aspect, the test compounds comprise polypeptides.

As used in each of the aspects and embodiments of the invention herein, the term "substantially purified" means that the polypeptides (or nucleic acids) of the invention are substantially free of cellular material, gel materials, culture medium, and contaminating polypeptides or nucleic acids (such as from nucleic acid libraries or expression products therefrom), except as described herein, when produced by recombinant techniques; or substantially free of chemical precursors or other chemicals when chemically synthesized, except as described herein.

As used in each of the aspects and embodiments of the invention herein, the term "polypeptide" is used in its broadest sense to refer to a sequence of subunit amino acids, amino acid analogs, or peptidomimetics. The subunits are linked by peptide bonds, except where noted. The polypeptides described herein may be chemically synthesized or recombinantly expressed, and may be present in a single copy, or in multiple copies (2 or more copies, preferably between 2 and 10; more preferably between 2 and 5 copies). In one non-limiting example, multiple copies of the polypeptide are present in a branched configuration by methods known to those of skill in the art and as disclosed herein, such as *Solid Phase Peptide Synthesis: A Practical Approach* (B. Atherton and R.C. Sheppard, eds., 1989. Oxford University Press, New York, NY); *Solid-Phase Synthesis: A Practical Guide* (S.A. Kates and F. Albericio, eds., 2000. Marcel Dekker, Inc., New York, NY); *Fmoc Solid Phase Peptide Synthesis: A Practical Approach* (W.C. Chan and P.D. White, eds., 2000. Oxford University Press, New York, NY). Technology for synthesis of

branched peptides is found in D.N. Posnett, H. McGrath and J.P. Tam (1988) "A novel method for producing anti-peptide antibodies." *Journal of Biological Chemistry* 263: 1719-1725.

The Tn determinant (GalNAc-α-O-Serine/Threonine) is a cryptic antigen that is "covered" on the surface of normal cells but expressed on many human tumor-associated structure (Babino et al., 2003). Lo-Man et al. (1999, 2001, 2004) proposed that antibodies against the Tn antigen should be effective therapeutic tools against cancers. These investigators have shown that clusters of GalNAc at the termini of branched structures elicit strong immunogenic responses. Clusters of the sugar show very different behavior than single residues (Iida et al., 1999; Vichier-Guerre et al., 2000). A synthetic multiple-antigen glycopeptide was shown to be immunogenic in mice and the presence of the antibodies partially protected mice from transplanted tumor cells. The branched molecule with GalNAc residues at the terminus of each branch, or a structure with three GalNAc residues at the terminus of each branch (Lo-Man et al., 2001), are strong antigenic structures, approximately 10^6-fold more antigenic than a molecule with a single antigen (Lo-Man et al., 1999; Vichier-Guerre et al., 2000). A human macrophage C-type lectin binds GalNAc-containing peptides with high specificity, including the Tn antigen, which is structurally similar to the active site of Gc-MAF. Glycopeptides containing multiple, closely clustered Tn determinants were bound by the lectin with up to 38-fold greater affinity than a single GalNAc attached to the peptide (Suzuki et al., 1996; Iida et al., 1999). The data indicate that the preferred binding of glycopeptides to the human macrophage lectin is as the trimeric protein (Iida et al., 1999), which is similar to observations that monoclonal antibodies recognize clustered GalNAc residues. Thus, clustering of the antigen is required for recognition by antibodies and the clusters are more effective in stimulating macrophages than single Tn molecules. In contrast to the GalNAc-bearing polypeptides, no adverse immunogenic response has been detected thus far to the mimetic polypeptides of this invention.

Where multiple copies of the polypeptides of the invention are present, the multiple copies can be multiple copies of the same polypeptide, or may include two or more different polypeptides, such as a branched multimer incorporating the polypeptide of SEQ ID NO:3 and SEQ ID NO:6, as disclosed below. Those of skill in the art will

understand that many such permutations are possible based on the teachings of the present invention.

Preferably, the substantially purified polypeptides of the present invention are chemically synthesized. Synthetic polypeptides, prepared using the well known techniques of solid phase, liquid phase, or peptide condensation techniques, or any combination thereof, can include natural and unnatural amino acids. Amino acids used for peptide synthesis may be standard Boc (N-α-amino protected N-α-t-butyloxycarbonyl) amino acid resin with the standard deprotecting, neutralization, coupling and wash protocols of the original solid phase procedure of Merrifield (1963, J. Am. Chem. Soc. 85:2149-2154), or the base-labile N-α-amino protected 9-fluorenylmethoxycarbonyl (Fmoc) amino acids first described by Carpino and Han (1972, *Journal of Organic Chemistry* 37:3403-3409). Both Fmoc and Boc N-α-amino protected amino acids can be obtained from Sigma-Aldrich, Cambridge Research Biochemical, or other chemical companies familiar to those skilled in the art. In addition, the polypeptides can be synthesized with other N-α-protecting groups that are familiar to those skilled in this art.

Solid phase peptide synthesis may be accomplished by techniques familiar to those in the art and provided, for example, in Stewart and Young (1984) *Solid Phase Synthesis*, Second Edition, Pierce Chemical Co., Rockford, Ill.; Fields and Noble (1990) *International Journal of Peptide and Protein Research* 35:161-214, or using automated synthesizers. The substantially purified polypeptides of the invention may comprise D-amino acids (which are resistant to L-amino acid-specific proteases in vivo), a combination of D- and L-amino acids, and various "designer" amino acids (e.g., β-methyl amino acids, C-α-methyl amino acids, and N-α-methyl amino acids, etc.) to convey special properties. Synthetic amino acids include ornithine for lysine, and norleucine for leucine or isoleucine.

In addition, the substantially purified polypeptides can have peptidomimetic bonds, such as ester bonds, to prepare peptides with novel properties. For example, a peptide may be generated that incorporates a reduced peptide bond, i.e., R_1-CH_2-NH-R_2, where R_1 and R_2 are amino acid residues or sequences. A reduced peptide bond may be introduced as a dipeptide subunit. Such a polypeptide would be resistant to protease activity, and would possess an extended half-live in vivo.

The substantially purified polypeptides of the invention may also be present as part of a fusion protein, in which case it may be desirable to synthesize the polypeptide using recombinant DNA technology. Such fusion proteins may include, for example, fusion with peptide transduction domains to permit movement of a fusion protein with the polypeptides of the invention to pass the cell membrane. As used herein, the term "transduction domain" means one or more amino acid sequence or any other molecule that can carry the active domain across cell membranes. These domains can be linked to other polypeptides to direct movement of the linked polypeptide across cell membranes. In some cases the transducing molecules do not need to be covalently linked to the active polypeptide. In a preferred embodiment, the transduction domain is linked to the rest of the polypeptide via peptide bonding. (See, for example, *Cell* 55: 1179-1188, 1988; *Cell* 55: 1189-1193, 1988; *Proc. Natl. Acad. Sci. U S A* 91: 664-668, 1994; *Science* 285: 1569-1572, 1999; *J. Biol. Chem.* 276: 3254-3261, 2001; and *Cancer Res* 61: 474-477, 2001).

In another example, the polypeptides of the invention may be present in a fusion protein with full length DBP, or with variations of various c-terminal fragments of DBP, as described in more detail below.

In a further example, the polypeptides of the invention can be fused or otherwise linked to therapeutic agents in order to enhance potential therapeutic effects of both agents. For example, monoclonal antibodies have been generated against a large number of cancers and other pathogenic agents for therapeutic use. Binding of these antibodies to the infectious agent is the first part of the therapy; phagocytosis of the antibody-bound agent by macrophages must occur to eliminate the agent from the body. Therefore, a combination of target-directed antibodies plus the polypeptides of the present invention would be an effective combination therapy. Many other such fusions or linkages to other therapeutic agents will be apparent to those of skill in the art based on the teachings herein.

It will be understood by those of skill in the art that such fusion proteins can comprise the addition of a polypeptide of the invention to the carboxy or amino terminal end of another polypeptide, or can comprise the placement of a polypeptide of the invention within another polypeptide. Those of skill in the art will recognize many such fusion proteins that can be made and used according to the teachings of the present invention.

The substantially purified polypeptides of the invention may be modified by, or combined with, non-polypeptide compounds to produce desirable characteristics, such modifications including but not limited to PEGylation with polyethylene glycol to improve *in vivo* residency time of the polypeptide, alkylation, phosphorylation, acylation, ester formation, amide formation, lipophilic substituent addition, and modification with markers including but not limited to fluorophores, biotin, dansyl derivatives, and radioactive moieties. Such compounds can be directly linked, or can be linked indirectly, for example via a spacer including but not limited to the B1 and/or B2 groups of general formulas 1-3 of the present invention, β-alanine, gamma-aminobutyric acid (GABA), L/D-glutamic acid, and succinic acid.

In a fifth aspect, the present invention provides pharmaceutical compositions, comprising one or more of the polypeptides disclosed herein, and a pharmaceutically acceptable carrier. Such pharmaceutical compositions are especially useful for carrying out the methods of the invention described below. For administration, the polypeptides are ordinarily combined with one or more adjuvants appropriate for the indicated route of administration. The compounds may be admixed with alum, lactose, sucrose, starch powder, cellulose esters of alkanoic acids, stearic acid, talc, magnesium stearate, magnesium oxide, sodium and calcium salts of phosphoric and sulphuric acids, acacia, gelatin, sodium alginate, polyvinylpyrrolidine, dextran sulfate, heparin-containing gels, and/or polyvinyl alcohol, and tableted or encapsulated for conventional administration. Alternatively, the compounds of this invention may be dissolved in physiological saline, water, polyethylene glycol, propylene glycol, carboxymethyl cellulose colloidal solutions, ethanol, corn oil, peanut oil, cottonseed oil, sesame oil, tragacanth gum, and/or various buffers. Other adjuvants and modes of administration are well known in the pharmaceutical art. The carrier or diluent may include time delay material, such as glyceryl monostearate or glyceryl distearate alone or with a wax, or other materials well known in the art. The polypeptides may be linked to other compounds to promote an increased half-life in vivo, such as polyethylene glycol. Such linkage can be covalent or non-covalent as is understood by those of skill in the art.

In a sixth aspect, the present invention provides substantially purified nucleic acid sequences encoding the polypeptides of the present invention, or functional equivalents thereof. Appropriate nucleic acid sequences according to this aspect of the invention will

be apparent to one of skill in the art based on the disclosure provided herein and the general level of skill in the art. In various preferred embodiments, the nucleic acid sequences comprise or consist of a nucleic acid sequence that encodes the amino acid according to **SEQ ID NOS:1-149**.

In a seventh aspect, the present invention provides expression vectors comprising DNA control sequences operably linked to the isolated nucleic acid molecules of the present invention, as disclosed above, or functional equivalents thereof. "Control sequences" operably linked to the nucleic acid sequences of the invention are nucleic acid sequences capable of effecting the expression of the nucleic acid molecules. The control sequences need not be contiguous with the nucleic acid sequences, so long as they function to direct the expression thereof. Thus, for example, intervening untranslated yet transcribed sequences can be present between a promoter sequence and the nucleic acid sequences and the promoter sequence can still be considered "operably linked" to the coding sequence. Other such control sequences include, but are not limited to, polyadenylation signals, termination signals, and ribosome binding sites. Such expression vectors can be of any type known in the art, including but not limited to plasmid and viral-based expression vectors.

In an eighth aspect, the present invention provides genetically engineered host cells comprising the expression vectors of the invention, or functional equivalents thereof. Such host cells can be prokaryotic cells or eukaryotic cells, and can be either transiently or stably transfected, or can be transduced with viral vectors. For example, such host cells can be bacterial cells (such as *E. coli*) or algal cells (such as *Chlamydomonas reinhardtii*), which do not generally glycosylate proteins. Thus, in one embodiment, bacterial, plant, or algal cells can be transfected with an expression vector expressing Domain III or full length DBP as a fusion with a polypeptide of the invention, to provide more efficient production of active Domain III or DBP in a non-mammalian system, as described below.

Thus, in a further embodiment of this eighth aspect, the invention provides improved methods for producing active Domain III and DBP analogs, comprising transfecting a bacterial, plant, or algal cell with an expression vector that expresses a fusion protein comprising (a) Domain III or DBP; and (b) a polypeptide according to the present invention, and isolating the fusion protein, wherein the fusion protein is a non-glycosylated but active DBP or Domain III analog. In a preferred embodiment, the fusion

protein comprises or consists of a polypeptide of the invention fused to DBP (NP-000574) or with C-terminal fragments of DBP, or functional equivalents thereof. Methods for isolating recombinant proteins from bacterial, plant, and algal cells is well known to those of skill in the art. This preferred embodiment also provides transgenic plants containing the expression vectors of the invention. For transferring the DNA into the plant cells, plant explants may suitably be co-cultivated with *Agrobacterium tumefaciens* or *Agrobacterium rhizogenes*. From the infected plant material (e.g., pieces of leaves, stem segments, roots, protoplasts or suspension-cultivated plant cells), whole plants may then be regenerated in a suitable medium which may contain antibiotics or biozides for the selection of transformed cells. The plants obtained in such a way may then be examined as to whether the introduced DNA is present or not. Other possibilities for introducing foreign DNA, such as using the biolistic method or by transforming protoplasts are known to the skilled person [cf. e.g. Willmitzer, L. (1993) Transgenic plants. In: *Biotechnology, A Multi-Volume Comprehensive Treatise* (H. J. Rehm, G. Reed, A. Puhler, P. Stadler, editors), Vol. 2, 627-659, VCH Weinheim-New York-Basel-Cambridge].

In a ninth aspect, the present invention provides methods for stimulating immune system activity in a subject, comprising administering to a subject an amount effective of a polypeptide according to the invention for stimulating immune system activity.

As used herein the phrase "stimulating immune system activity" means to increase the activity of one or more components of the immune system, including phagocytes, macrophages, and neutrophils. Substances secreted by activated macrophages in turn stimulate other cells of the immune system, in particular dendritic cells. As such, methods for stimulating immune system activity are broadly useful for treating cancer, viral infections, angiogenesis-mediated disorders, bone disorders, immune-suppressed disorders, pain, and as adjuvants for vaccinations.

Thus, in a tenth aspect, the present invention provides methods for treating one or more disorders in a subject, selected from the group consisting of viral infection, cancer, bone disorders, immune suppressed disorder, pain, and angiogenesis-mediated disorders, comprising administering to a subject an amount effective of a polypeptide according to the invention for treating the disorder.

In an eleventh aspect, the present invention provides methods for promoting an improved immune system response to a vaccination, comprising administering to a subject

receiving a vaccination an amount effective of a polypeptide according to the invention for promoting an improved immune system response to the vaccination.

In a preferred embodiment of the ninth, tenth, and eleventh aspects of the invention, the subject is a mammal; in a more preferred embodiment, the subject is a human.

In carrying out the methods for promoting an improved immune system response to the vaccination according to the present invention, the polypeptides, or pharmaceutical compositions thereof, of the invention can be administered before, simultaneously with, or after vaccine administration. Where the vaccine is administered on multiple occasions, the polypeptides of the invention can be administered together with a single vaccine administration, or with multiple vaccine administrations. In a preferred embodiment, the polypeptides are administered simultaneously with the one or more rounds of vaccination. Preferred classes of patients include populations at high risk for viral infection, including but not limited to children, health care workers, senior citizens, and those at high risk of specific types of viral infection, such as partners of HIV infected individuals, sex trade workers, and intravenous drug users.

In various embodiments of the ninth, tenth, and eleventh aspects of the invention, administration of the polypeptide is accomplished via direct delivery (for example, by injection), or by gene therapy via administration of an appropriate expression vector of the invention which can be expressed in the target tissue. In embodiments employing gene therapy, it is preferred to use viral expression vectors, including but not limited to adenoviral and retroviral vectors.

In carrying out the methods of the invention, the polypeptides or pharmaceutical compositions thereof may be made up in a solid form (including granules, powders, transdermal or transmucosal patches or suppositories) or in a liquid form (*e.g.*, solutions, suspensions, or emulsions), and may be subjected to conventional pharmaceutical operations such as sterilization and/or may contain conventional adjuvants, such as stabilizers, wetting agents, emulsifiers, preservatives, cosolvents, suspending agents, viscosity enhancing agents, ionic strength and osmolality adjustors and other excipients in addition to buffering agents. Suitable water soluble preservatives which may be employed in the drug delivery vehicle include sodium bisulfite, sodium thiosulfate, ascorbate, benzalkonium chloride, chlorobutanol, thimerosal, phenylmercuric borate, parabens, benzyl

alcohol, phenylethanol or antioxidants such as Vitamin E and tocopherol and chelators such as EDTA and EGTA. These agents may be present, generally, in amounts of about 0.001% to about 5% by weight and, preferably, in the amount of about 0.01 to about 2% by weight.

For administration, the polypeptides are ordinarily combined with one or more adjuvants appropriate for the indicated route of administration. The polypeptides may be admixed with alum, lactose, sucrose, starch powder, cellulose esters of alkanoic acids, stearic acid, talc, magnesium stearate, magnesium oxide, sodium and calcium salts of phosphoric and sulphuric acids, acacia, gelatin, sodium alginate, polyvinylpyrrolidine, and/or polyvinyl alcohol, and tableted or encapsulated for conventional administration. Alternatively, the polypeptides of this invention may be dissolved in physiological saline, water, polyethylene glycol, propylene glycol, carboxymethyl cellulose colloidal solutions, ethanol, corn oil, peanut oil, cottonseed oil, sesame oil, tragacanth gum, and/or various buffers. Other adjuvants and modes of administration are well known in the pharmaceutical art. The carrier or diluent may include time delay material, such as glyceryl monostearate or glyceryl distearate alone or with a wax, or other materials well known in the art.

For use herein, the polypeptides may be administered by any suitable route, including local delivery, parentally, transdermally, by inhalation, or topically in dosage unit formulations containing conventional pharmaceutically acceptable carriers, adjuvants, and vehicles. The term parenteral as used herein includes, subcutaneous, intravenous, intramuscular, intrasternal, intratendinous, intraspinal, intracranial, intrathoracic, infusion techniques or intraperitoneally. Suppositories for rectal administration of the active agents in combination with the vaccines can be prepared by mixing the drug with a suitable non-irritating excipient such as cocoa butter and polyethylene glycols which are solid at ordinary temperatures, but liquid at the rectal temperature and will therefore melt in the rectum and release the drug.

Solid dosage forms for oral administration may include capsules, tablets, pills, powders and granules. In such solid dosage forms, the polypeptides may be admixed with at least one inert diluent such as alum, sucrose, lactose or starch. Such dosage forms may also comprise, as is normal practice, additional substances other than inert diluents, e.g., lubricating agents such as magnesium stearate. In the case of capsules, tablets and pills, the dosage forms may also comprise buffering agents. Tablets and pills can additionally

be prepared with enteric coatings. Liquid dosage forms for oral administration may include pharmaceutically acceptable emulsions, solutions, suspensions, syrups and elixirs containing inert diluents commonly used in the art, such as water. Such compositions may also comprise adjuvants, such as wetting agents, emulsifying and suspending agents and sweetening, flavoring and perfuming agents.

As used herein for all of the methods of the invention, an "amount effective" of the polypeptides is an amount that is sufficient to provide the intended benefit of treatment. An effective amount of the polypeptides that can be employed ranges generally between about 0.01 μg/kg body weight and about 10 mg/kg body weight, preferably ranging between about 0.05 μg/kg and about 5 mg/kg body weight. However, dosage levels are based on a variety of factors, including the type of disorder, the age, weight, sex, medical condition of the individual, the severity of the condition, the route of administration, and the particular compound employed. Thus, the dosage regimen may vary widely, but can be determined routinely by a physician using standard methods.

Tumors susceptible of treatment by the methods of the invention include lymphomas, sarcomas, melanomas, neuroblastomas, carcinomas, leukemias, and mesotheliomas. Methods of tumor treatment according to the invention can be used in combination with surgery on the subject, wherein surgery includes primary surgery for removing one or more tumors, secondary cytoreductive surgery, and palliative secondary surgery. In a further embodiment, the methods further comprise treating the subject with chemotherapy and/or radiation therapy, which can reduce the chemotherapy and/or radiation dosage necessary to inhibit tumor growth and/or metastasis. As used herein, "radiotherapy" includes but is not limited to the use of radio-labeled compounds targeting tumor cells. Any reduction in chemotherapeutic or radiation dosage benefits the patient by resulting in fewer and decreased side effects relative to standard chemotherapy and/or radiation therapy treatment. In this embodiment, the polypeptide may be administered prior to, at the time of, or shortly after a given round of treatment with chemotherapeutic and/or radiation therapy. In a preferred embodiment, the polypeptide is administered prior to or simultaneously with a given round of chemotherapy and/or radiation therapy. In a most preferred embodiment, the polypeptide is administered prior to or simultaneously with each round of chemotherapy and/or radiation therapy. The exact timing of compound administration will be determined by an attending physician based on a number of factors,

but the polypeptide is generally administered between 24 hours before a given round of chemotherapy and/or radiation therapy and simultaneously with a given round of chemotherapy and/or radiation therapy. The tumor treating methods of the invention are appropriate for use with chemotherapy using one or more cytotoxic agent (ie., chemotherapeutic), including, but not limited to, cyclophosphamide, taxol, 5-fluorouracil, adriamycin, cisplatinum, methotrexate, cytosine arabinoside, mitomycin C, prednisone, vindesine, carbaplatinum, and vincristine. The cytotoxic agent can also be an antiviral compound which is capable of destroying proliferating cells. For a general discussion of cytotoxic agents used in chemotherapy, see Sathe, M. et al. (1978) *Cancer Chemotherapeutic Agents: Handbook of Clinical Data,* hereby incorporated by reference. When administered as a combination, the therapeutic agents can be formulated as separate compositions that are given at the same time or different times, or the therapeutic agents can be given as a single composition. The methods of the invention are also particularly suitable for those patients in need of repeated or high doses of chemotherapy and/or radiation therapy.

Any infection to which the immune system responds can be treated according to the methods of the invention. Infections, as used herein, are broadly defined to mean situations when the invasion of a host by an agent is associated with the clinical manifestations of infection including, but not limited to, at least one of the following: abnormal temperature, increased heart rate, abnormal respiratory rate, abnormal white blood cell count, fatigue, chills, muscle ache, pain, dizziness, dehydration, vomiting, diarrhea, organ dysfunction, and sepsis. Such infections may be bacterial, viral, parasitic, or fungal in nature. The method may further comprise combinatorial treatment with other anti-infective agents, such as antibiotics. Viruses susceptible to treatment according to the methods of the invention include, but are not limited to adenoviruses, rhinoviruses, rabies, murine leukemia virus, poxviruses, lentiviruses, retroviruses; including disease-causing viruses such as human immunodeficiency virus, hepatitis A and B viruses, herpes simplex virus, cytomegalovirus, human papilloma virus, coxsackie virus, smallpox, hemorrhagic virus, ebola, and human T-cell-leukemia virus. Bacteria susceptible to treatment include, but are not limited to gram negative bacteria and gram-positive bacteria, including but not limited to *Escherichia coli, Staphylococcus aureus, Staphylococcus epidermidis, Streptococcus pneumoniae, Mycobacterium tuberculosis, Neisseria*

gonorrhoeae, Neisseria meningitis, Bordetalla pertussis, Salmonella thyhimurium, Salmonella choleraesuis, and Enterobacter cloacae, as well as bacterium in the genus *Acinetobacter, Actinomyes, Bacilus, Bordetella, Borrelia, Brocella, Clostridium, Corynebacterium, Campylobacter, Deincoccus, Escherichia, Enterobacter, Enterrococcus, Eubacterium, Flavobacterium, Francisella Glueonobacter, Heliobacter, Intrasporangium, Janthinobacterium, Klebsiella, Kingella, Legionella, Leptospira, Mycobacterium, Moraxella, Neisseria, Oscillospira, Proteus, Psendomonas, Providencia, Rickettsia, Salomonella, Staphylococcus, Shigella, Spirilum, Streptococcus, Treponema, Ureplasma, Vibrio, Wolinella, Wolbachia, Xanthomonas, Yersinis,* and *Zoogloea* Parasitic agents that can be treated by the methods of this aspect of the invention include, but are not limited to Plasmodium, Leishmania, Trypanosomes, Trichomona, and including but not limited to parasitic agents in the phylums *Acanthocephela, Nematoda, Nemtomorpha, Platyhelminthes, Digena, Eucestoda, Turbellaria, Sarcomastigophora* and *Protozoa* including but not limited to species *Giardia duodenalis, Cryptosporidium parvum, Cyclospora cayetanenis, Toxoplasma gondii, Trichinella spiralis, Tanenia saginata, Taenia solium, Wuchereria bancrofti, Brugia malay, Brugia timori, Onchocerca vovulus, Loa loa, Dracunculus medinensis, Mansonella streptocera, Mansonella perstans, Mansonella ozzardi, Schistosoma hematobium, Schistosoma mansoni, Schistosoma japonicum, Ascaris lumbricoides, Entrobius vermicularis, Trichuris trichiura, Ancylostoma brasiliense, Ancylostoma duodenale, Necator ameicanus, Strongyloides stercoralis, Capillaria hepatica, Angiostrongylus cantonensis, Fasciola hepatica, Fasciola gigantica, Fasciolopsis buski, Chlonrchis sinensis, Heterophyes heterophyes, Paragonimus westermani, Diphyllobothrium latum, Hymenolepis nana, Hymenolepis dimunuta, Echinococcus granulosus, Dipylidium caninum, Entamoeba histolytica, Entamoeba coli, Entamoeba hartmanni, Dientamoeba fragilis, Endolimax nana, Lodomoeba butschilii, Blastocystis hominis, Giardia intetinalis, Chilomastix menili, Blantidium coli, Trichomonas vaginalis, Leishmania donovani, Trypanosoma cruzi, Sarcocystis lindemanni,* and *Babesis argentina.* Fungal infections that can be treated by the methods of this aspect of the invention include, but are not limited to fungal meningitis, histoplasmosis, *Candida albicans* infection, as well as *Blastomyces dermatitidis Histotplasma capsulatum, Cryptococcus neoformans, Sporothrix schenckii, Aspergillus fumigatus* and *Pneumocystis carinii* infections.

Angiogenesis-mediated disorders susceptible of treatment by the methods of the invention include solid and blood-borne tumors including but not limited to melanomas, carcinomas, sarcomas, rhabdomyosarcoma, retinoblastoma, Ewing sarcoma, neuroblastoma, osteosarcoma, and leukemia; diabetic retinopathy, rheumatoid arthritis, retinal neovascularization, choroidal neovascularization, macular degeneration, corneal neovascularization, retinopathy of prematurity, corneal graft rejection, neovascular glaucoma, retrolental fibroplasia, epidemic keratoconjunctivitis, Vitamin A deficiency, contact lens overwear, atopic keratitis, superior limbic keratitis, pterygium keratitis sicca, sjogrens, acne rosacea, phylectenulosis, syphilis, Mycobacteria infections, lipid degeneration, chemical burns, bacterial ulcers, fungal ulcers, Herpes simplex infections, Herpes zoster infections, protozoan infections, Kaposi's sarcoma, Mooren ulcer, Terrien's marginal degeneration, marginal keratolysis, traum, systemic lupus, polyarteritis, Wegeners sarcoidosis, scleritis, Steven's Johnson disease, radial keratotomy, sickle cell anemia, sarcoidosis, pseudoxanthoma elasticum, Pagets disease, vein occlusion, artery occulsion, carotid obstructive disease, chronic uveitis, chronic vitritis, Lyme's disease, Eales disease, Bechets disease, myopia, optic pits, Stargarts disease, pars planitis, chronic retinal detachment, hyperviscosity syndromes, toxoplasmosis, post-laser complications, abnormal proliferation of fibrovascular tissue, hemangiomas, Osler-Weber-Rendu, acquired immune deficiency syndrome, ocular neovascular disease, osteoarthritis, chronic inflammation, Crohn's disease, ulceritive colitis, psoriasis, atherosclerosis, and pemphigoid. (See U.S. Patent No. 5,712,291)

Bone disorders susceptible of treatment by the methods of the invention include but are not limited to bone fractures, defects, and disorders resulting in weakened bones such as ostepetrosis, osteoarthritis, rheumatoid arthritis, Paget's disease, osteohalisteresis, osteomalacia, periodontal disease, bone loss resulting from multiple myeloma and other forms of cancer, bone loss resulting from side effects of other medical treatment (such as steroids), age-related loss of bone mass and genetic diseases such as osteopetrosis. The polypeptides of the invention can be used alone or together with other compounds to treat bone disorders.

Immune suppressed illnesses or conditions susceptible of treatment by the methods of the invention include but are not limited to severe combined immune deficiency syndrome, acquired immune deficiency syndrome, and at risk populations including but

not limited to malnourished individuals and senior citizens. Also susceptible of treatment are diseases such as cancer and viral infections, such as with HIV, in which the pathogenic agent or cell carries or produces an enzyme, N-acetyl-galactosaminidase, that removes GalNAc from Gc-MAF and thus destroys the activity of MAF. An effect of this enzymatic activity is an immuno-suppressed state that can be overcome by treatment with the polypeptides of the invention. Infectious agents may also cause destruction of important cells involved in modifying the precursor Gc protein to the active form Gc-MAF. For example, HIV causes loss of T-lymphocytes, which contain a sialidase that is involved in processing the precursor protein to its active form. Therefore, an immunosuppressed state can be caused by a decrease in processing the Gc-MAF precursor to the active protein and by further removal of the required sugar, which inactivates the protein. The polypeptides of the invention can be used alone or together with other compounds to treat immune suppressed illnesses.

The polypeptides of the invention can also be used as an analgesic to treat pain resulting from any cause, such as an underlying disease or trauma.

In a twelfth aspect, the present invention provides methods for identifying a GalNAc mimetic compound, comprising:

a) contacting a plurality of test compounds with a GalNAc-specific lectin under conditions to promote binding of the GalNAc-specific lectin with a GalNAc mimetic compound;

b) removing unbound test compounds;

c) repeating steps (a) and (b) a desired number of times;

d) contacting test compounds bound to the GalNAc-binding protein with an amount effective of a polypeptide comprising or consisting of an amino acid sequence according to **SEQ ID NOS:1-149** to displace the bound test compounds if the bound test compounds are acting as GalNAc-mimetics; and

e) identifying those test compounds that are displaced from the GalNAc binding protein by a polypeptide comprising or consisting of an amino acid sequence according to **SEQ ID NOS:1-149**, wherein such test compounds are GalNAc mimetic compounds.

As used herein the term "contacting" means in vivo or in vitro, preferably in vitro, under suitable conditions for promoting binding of the test polypeptides or compounds to

GalNAc-specific lectin. Such techniques are known to those of skill in the art. The assays of the invention can be carried out, for example, as described herein. Modifications of these techniques are well within the level of those of skill in the art with respect to appropriate conditions for contacting as recited above that promote the appropriate binding, as well as techniques for removing unbound polypeptides and identifying the resulting GalNAc-polypeptide mimetics.

As recited in step (c), steps (a) and (b) can be carried out a desired number of additional times, which can be 0 repeats to as many as desirable, preferably between 1 and 5 repeats of step (a) and (b).

Suitable GalNAc-specific lectins for use with the present invention are as described above. The test compounds can be, for example, polypeptides, small molecules, or nucleic acids. In a preferred embodiment, the test compounds are polypeptides.

In a further preferred embodiment of the twelfth aspect, the methods further comprise synthesizing the GalNAc-polypeptide mimetics or test compound mimetics, using methods for synthesis known to those of skill in the art, and as disclosed herein.

In a further aspect, the present invention provides GalNAc mimetic polypeptides or compounds made according to the methods of the twelfth aspect of the invention.

The test compounds (or test polypeptides) of the twelfth aspect can, for example, be from compound libraries, expression libraries, and the like.

The present invention may be better understood with reference to the accompanying examples that are intended for purposes of illustration only and should not be construed to limit the scope of the invention, as defined by the claims appended hereto.

Examples

Because little more than the sugar and a few amino acids of DBP show phenotypic macrophage activation (Schneider et al., 2003), we designed a polypeptide structure that provides activation but which cannot be inactivated by deglycosylation. Amino acid sequences were identified that would mimic protein-bound GalNAc by screening a phage display library by first selecting phage particles that bind to GalNAc-specific lectins and subsequent elution with free GalNAc. An example of lectins that are useful in the screen is one purified from the snail *Helix pomatia*, which is highly specific for GalNAc (Hammerström and Kabat, 1971) and also binds specifically to the active form of Gc-

MAF that contains GalNAc (Kanan et al., 2000). With the lectin as an analog of the receptor on macrophage cells, a polypeptide that binds to the lectin should mimic the structure of Gc-MAF.

The phage display polypeptide libraries were mixed with the *Helix pomatia* lectin conjugated to agarose beads (Sigma-Aldrich Co.). Phage particles that bound to the lectin were recovered by centrifugation, the complexes were washed and bound phage particles were released by a wash with 100 mM GalNAc. The phage were amplified and the 'panning' with the lectin-agarose conjugate was repeated two more times. Panning of the original library was also done with another GalNAc-specific lectin from *Vicia villosa* attached to agarose beads (Sigma-Aldrich Co.). Phage particles that bound to the lectin and were subsequently eluted by competition with free GalNAc were replicated, and the DNA of each was sequenced to derive the amino acid sequences of the variable region.

Table 1 shows amino acid sequences that were derived from the lectin screen. Two phage libraries were used to generate these data, (1) phage with a 7-mer variable region flanked by cysteine residues to allow loop formation by disulfide bond formation ("constrained") and (2) phage particles with a 7-mer variable region ("non-constrained").

Table 1. Amino acid sequences derived from DNA sequences of phage particles selected with GalNAc-specific lectins.

7-Mer flanked by C (*H. pomatia* lectin) **(Constrained)**

1. CNSTTPASC **(SEQ ID NO:1)**
2. CDPTESSFC **(SEQ ID NO:2)**
3. CSPHTKDWC **(SEQ ID NO:3)**
4. CGPDPPRDC **(SEQ ID NO:4)**
5. CNWHWITNC **(SEQ ID NO:5)**
6. CSVSQVTTC **(SEQ ID NO:6)**
7. CEQTLTPQC **(SEQ ID NO:7)**
8. CLSPLSPVC **(SEQ ID NO:8)**
9. CLTSSVSTC **(SEQ ID NO:9)**
10. CVDIPSFQC **(SEQ ID NO:10)**
11. CTVSGHQDC **(SEQ ID NO:11)**
12. CLHPMLTDC **(SEQ ID NO:12)**
13. CCALDLETC **(SEQ ID NO:13)**
14. CDSPNHRLC **(SEQ ID NO:14)**
15. CMTSFNLSC **(SEQ ID NO:15)**

7-Mer flanked by C (VVA Lectin) **(Constrained)**

16. CLNNSHAEC **(SEQ ID NO:16)**
17. CPQNTAKAC **(SEQ ID NO:17)**

18. CPFRSHQRC **(SEQ ID NO:18)**
19. CPLLPWSPC **(SEQ ID NO:19)**
20. CSSIPGPSC **(SEQ ID NO:20)**
21. CVNTSSDSC **(SEQ ID NO:21)**
22. CPSRTPNHC **(SEQ ID NO:22)**
23. CYSHNLAEC **(SEQ ID NO:23)**
24. CTPPKTRTC **(SEQ ID NO:24)**
25. CDPMRPSMC **(SEQ ID NO:25)**
26. CPRLSQSPC **(SEQ ID NO:26)**
27. CSLDYPDSC **(SEQ ID NO:27)**

7-Mer (*H. pomatia* lectin) **(Non-constrained)**

28. SHVQCVN **(SEQ ID NO:28)**
29. IPNPSIR **(SEQ ID NO:29)**
30. RIRVIRE **(SEQ ID NO:30)**
31. EYDNSPP **(SEQ ID NO:31)**
32. RTEHAGF **(SEQ ID NO:32)**
33. YVSDYDW **(SEQ ID NO:33)**
34. SDRPSLK **(SEQ ID NO:34)**
35. YWSPSLK **(SEQ ID NO:35)**
36. LPLKLLW **(SEQ ID NO:36)**
37. HAHKVGT **(SEQ ID NO:37)**
38. ALKPMSH **(SEQ ID NO:38)**
39. TPDYLAA **(SEQ ID NO:39)**
40. TPPAAAR **(SEQ ID NO:40)**
41. YPSTFTR **(SEQ ID NO:41)**
42. VCRPPCP **(SEQ ID NO:42)**
43. MPLPFPT **(SEQ ID NO:43)**
44. ASDTIQT **(SEQ ID NO:44)**
45. SYYMRDP **(SEQ ID NO:45)**
46. SQDPSQL **(SEQ ID NO:46)**
47. LQTFPKP **(SEQ ID NO:47)**
48. LSNTFGL **(SEQ ID NO:48)**
49. IPWASLL **(SEQ ID NO:49)**
50. ITANTLS **(SEQ ID NO:50)**
51. KISLGGL **(SEQ ID NO:51)**
52. APQPYRQ **(SEQ ID NO:52)**
53. HSPADTP **(SEQ ID NO:53)**
54. TLPALAL **(SEQ ID NO:54)**
55. NAQKSTL **(SEQ ID NO:55)**
56. ADEALTL **(SEQ ID NO:56)**
57. SLSASRI **(SEQ ID NO:57)**
58. GSASALA **(SEQ ID NO:58)**
59. SNLSGST **(SEQ ID NO:59)**
60. QVPVHPS **(SEQ ID NO:60)**
61. IPGTVHV **(SEQ ID NO:61)**
62. TTTSFRA **(SEQ ID NO:62)**

63. ATSLVNL (**SEQ ID NO:63)**
64. ASGMVFM (**SEQ ID NO:64)**
65. QLFPCMS (**SEQ ID NO:65)**
66. LITHPIV (**SEQ ID NO:66)**
67. YTLGDPS (**SEQ ID NO:67)**
68. LRPMTVP (**SEQ ID NO:68)**
69. LGTTPQL (**SEQ ID NO:69)**
70. TAFLGQH (**SEQ ID NO:70)**
71. YHQRGPV (**SEQ ID NO:71)**
72. SHLKSMS (**SEQ ID NO:72)**
73. HMSRMAN (**SEQ ID NO:73)**
74. ASTQLLP (**SEQ ID NO:74)**
75. SALWSPV (**SEQ ID NO:75)**
76. VLEYSPS (**SEQ ID NO:76)**
77. SQPATKR (**SEQ ID NO:77)**

<u>7-Mer (VVA lectin) **(Non-constrained)**</u>

78. DPKVRTA (**SEQ ID NO:78)**
79. FERDLPW (**SEQ ID NO:79)**
80. NRAQNRK (**SEQ ID NO:80)**
81. AYPFIFR (**SEQ ID NO:81)**
82. LGILCSR (**SEQ ID NO:82)**
83. GEYVTLR (**SEQ ID NO:83)**
84. HLDSSNS (**SEQ ID NO:84)**
85. LNTARHT (**SEQ ID NO:85)**
86. TSVLRPG (**SEQ ID NO:86)**
87. HVPPHAR (**SEQ ID NO:87)**
88. GPRTHNS (**SEQ ID NO:88)**
89. QMPAVPS (**SEQ ID NO:89)**
90. WNPTYPP (**SEQ ID NO:90)**
91. HQDLRRQ (**SEQ ID NO:91)**
92. GELPFNP (**SEQ ID NO:92)**
93. SYLQLPP (**SEQ ID NO:93)**
94. HVLPVPL (**SEQ ID NO:94)**
95. ASTYLLG (**SEQ ID NO:95)**
96. YERAGSH (**SEQ ID NO:96)**
97. WQPHSHP (**SEQ ID NO:97)**
98. DSLTPET (**SEQ ID NO:98)**
99. HPNRFDH (**SEQ ID NO:99)**
100. NNAILHP (**SEQ ID NO:100)**
101. RLPGHPS (**SEQ ID NO:101)**
102. HAPHLWD (**SEQ ID NO:102)**
103. SPNVPPY (**SEQ ID NO:103)**
104. IPHLSTL (**SEQ ID NO:104)**
105. DYPASSF (**SEQ ID NO:105)**
106. FPRMQPL (**SEQ ID NO:106)**
107. HNKTSYY (**SEQ ID NO:107)**
108. THHPIHK (**SEQ ID NO:108)**

109. TSPLPYW **(SEQ ID NO:109)**
110. ASPHPAV **(SEQ ID NO:110)**
111. YSLQHML **(SEQ ID NO:111)**
112. FPTTYWI **(SEQ ID NO:112)**
113. CLRAMND **(SEQ ID NO:113)**
114. NKLPPLF **(SEQ ID NO:114)**
115. SGLQQPR **(SEQ ID NO:115)**
116. QATKVRS **(SEQ ID NO:116)**
117. SPTSARS **(SEQ ID NO:117)**
118. ASHPSSA **(SEQ ID NO:118)**
119. QPIGAQR **(SEQ ID NO:119)**
120. LDTHHLQ **(SEQ ID NO:120)**
121. QPSLHIS **(SEQ ID NO:121)**
122. SSFLLGW **(SEQ ID NO:122)**
123. SQQLASA **(SEQ ID NO:123)**
124. QPLRAGS **(SEQ ID NO:124)**
125. EPLRRDT **(SEQ ID NO:125)**
126. APFLSRL **(SEQ ID NO:126)**
127. IPHLKLP **(SEQ ID NO:127)**
128. LPMYSVQ **(SEQ ID NO:128)**
129. MLPSCAD **(SEQ ID NO:129)**
130. LLLTSPG **(SEQ ID NO:130)**
131. SPAGAYY **(SEQ ID NO:131)**
132. TGPMPAP **(SEQ ID NO:132)**
133. YKSTLNN **(SEQ ID NO:133)**
134. SLSVSTR **(SEQ ID NO:134)**
135. RPLQNNY **(SEQ ID NO:135)**
136. VVTLSTL **(SEQ ID NO:136)**
137. HNLHGNL **(SEQ ID NO:137)**
138. THQCRQC **(SEQ ID NO:138)**
139. VSPFIRS **(SEQ ID NO:139)**
140. APRTAFP **(SEQ ID NO:140)**
141. HGTMTVM **(SEQ ID NO:141)**
142. NRLAQVH **(SEQ ID NO:142)**
143. ALLALIP **(SEQ ID NO:143)**
144. LPYGRQH **(SEQ ID NO:144)**
145. ARATHPP **(SEQ ID NO:145)**
146. LQPWVTP **(SEQ ID NO:146)**
147. RGITPFL **(SEQ ID NO:147)**
148. SADASPQ **(SEQ ID NO:148)**
149. VSAHQAS **(SEQ ID NO:149)**

Figure 1 shows a flowchart description of the algorithm used to search for patterns among these groups of sequences. The algorithm was developed to determine frequencies

of functionally similar dimers, trimers and pentamers, for example. Those that appear most frequently comprise the core of the mimetic. A reduced number of sequences emerge after several rounds of enrichment by the lectin screen.

In order to derive the consensus sequence from the sequences obtained from phage display, a code is written in Java language (1.4.1_02), which is a stand-alone program. The program takes all the sequences that are separated by a separator (|) into a single string as an input. This string is converted into substrings and is stored in a vector, and then these substrings are converted into six-letter codes and transforms into triplets.

Example:

Actual sequence is **AQQSQVY|AQQSQAY**

Converted sequence will be **AXXOXUY, AXXOXAY**

Triplets obtained are **AXX XXO XOX OXU XUY|AXX XXO XOX OXA XAY**

Then the program calculates the position, total and frequency of all the triplets and displays in the form of matrix. Total is sum of the individual triplets occurring in all the sequences and Frequency is (Total/Length of the sequence)*100.

Example:

*	1	2	3	4	5	TOT	Freq=(TOT/Len)*100
AXX	2	0	0	0	0	2	20.0%
OXA	0	0	0	1	0	1	10.0%
OXU	0	0	0	1	0	1	10.0%
XAY	0	0	0	0	1	1	10.0%
XOX	0	0	2	0	0	2	20.0%
XUY	0	0	0	0	1	1	10.0%

XXO | 0 2 0 0 0 2 20.0%

Triplet that occur more than one time are taken and calculated again considering the amino acid immediately before and after the triplet from the sequence.

Example:

Triplets that are occurring more than one time are: **AXX, XOX, XXO**

Amino acid before and after triplet from the sequence are displayed

Converted: **AXXO;** Original: **AQQS**

Converted: **AXXO**; Original: **AQQS**

Converted: **XXOXU**; Original: **QQSQV**

Converted: **XXOXA**; Original: **QQSQA**

Converted: **AXXOX**; Original: **AQQSQ**

Converted: **AXXOX**; Original: **AQQSQ**

Results of these pairings were as follows:

Table 2: Amino acid pairs (Constrained)	
1-mer	A (8,4.97%), D (5,3.11%), F (5,3.11%), H (9, 5.59%), I (6, 3.73%), L (13, 8.07%), N (12. 7.45%), P (26, 16.15%), Q (9, 5.59%), R (7, 4.35%), S (24, 14.91%),T (15, 9.32%), V(5, 3.11%)
2-mer	DP (2, 1.45%), GP (2, 1.45%), HA (2, 1.45%), HQ(2, 1.45%), IT(2, 1.45%), LL(4, 2.9%), LS(3, 2.17%), LS(3,2.17%), NN(2, 1.45%), NS(3,2.17%), PF(2, 1.45%), PL(3, 2.17%), PP(3, 2.17%), PQ(2, 1.45%), PS(2, 1.45%), PV(2, 1.45%), QT(2, 1.45%), SH(2, 1.45%), SP(5, 3.62%), SR(2, 1.45%), SS(3, 2.17%), TA(2, 1.45%), TP(3, 2.17%), TT(2, 1.45%)
3-mer	LSP (2, 1.74%), SPL (2, 1.74%)

Table 3: Amino acid pairs (Non-constrained)

1-mer	A (49, 7.45%), C (6, .91%), D (21, 3.19%), E (10, 1.52%), F(18, 2.74%), G(23, 3.5%), H(40, 6.08%), I(20, 3.04%), K(16, 2.43%), L(73, 11.09%), M(14, 2.13%), N(23, 3.5%), P(88, 13.37%), Q(30, 4.56%), R(39, 5.93%), S(75, 11.4%), T(50, 7.6%),V(27, 4.1%), W(11, 167%), Y(25, 3.85%)
2-mer	'AA'(3,.05%),'AD'(2,035%),'AG'(2,035%),'AL'(6,1.06%),'AN'(2,035%),'AP'(2,35),'AQ'(3,.53%),'AR'(4,.71%),'AS'(10,1.77%),'AT'(3,53%),'AV'(2,035%),'DL'(2,03%),'DP'(4,.71%),'DS'(2,035%),'DT'(3,.53%),'DY'(3,.53%),'ER'(2,035%),'FP'(5,.89%),'FR'(2,.35%),'GE'(2,.35%),'GL'(3,.53%),'GP'(2,.35%),'GS'(3..53%),'GT'(3,.53%),'HA'(4,.71%),'HH'(2,.35%),'HK'(2,.35%),'HL'(5,.89%),'HM'(2,.35%),'HN'(2,.35%),'HP'(9,1.6%),'HQ'(2,.35%),'HS'(2,.35%),'HV'(4,.71%),'IL'(2,.35%),'IP'(4,.71%),'IR'(3,.53),'IS'(2,.35%),'IT'(2,.35%),'KL'(2,.35%),'KP'(2,.35%),'KS'(2,035%),'KV'(3,.53%),'LA'(3,.53%),'LD'(2,035%),'LF'(2,035%),'LG'(),'LH'(2,035%),'LK'(5,.89%),'LL'(4,.71%),'LP'(11,1.95%),'LQ'(5,.89%),'LR'(5,.89%),'LS'(5,.89%),'LT'(2,035%),'LW'(3,.53%),'MP'(2,035%),'MS'(4,.71%),'NA'(2,035%),'NK'(2,035%),'NL'(2,035%),'NP'(3,.53%),'NR'(3,.53%),'NS'(3,.53%),'NT'(3,.53%),'PA'(7,1.24%),'PC'(2,035%),'PF'(3,.53%),'PG'(3,.53%),'PH'(),'PI'(3,.53%),'PK'(2,.35%),'PL'(6,1.06%),'PM'(2,.35%),'PN'(3,.53%),'PP'(8,1.42%),'PQ'(2,.35%),'PR'(3,.53%),'PS'(12,2.13%),'PT'(4,.71%),'PV'(4,.71%),'PW'(2,.35%),'PY'(3,.53%),'QD'(2,.35%),'QH'(2,.35%),'QL'(5,.89%),'QP'(7,1.24%),'RA'(4,.71%),'RD'(2,.35%),'RI'(2,.35%),'RM'(2,.35%),'RP'(4,.71%),'RQ'(2,.35%),'RS'(2,.35%),'RT'(3,.53%),'SA'(6,1.06%),'SD'(3,.53%),'SF'(2,.35%),'SG'(3,.53%),'SH'(6,1.06%),'SL'(9,1.6%),'SN'(3,.53%),'SP'(9,1.6%),'SQ'(3,.53%),'SR'(3,.53%),'SS'(3,.53%),'ST'(6,1.06%),'SY'(3,.53%),'TA'(4,.71%),'TF'(3,.53%),'TH'(),'TK'(2,.35%),TL'(7,1.24%),'TP'(5,.89%),'TS'(6,1.06%),'TT'(4,.71%),'TV'(2,.35%),'TY'(3,.53%),'VH'(2,.35%),'VL'(3,.53%),'VN'(2,.35%),'VP'(6,1.06%),'VR'(2,.35%),'WS'(2,.35%),'YD'(2,.35%),'YL'(3,.53%),'YP'(4,.71%),'YS'(2,.35%),'YV'(2,.3%),'YW'(3,.53%),'YY'(2,.35%)
3-mer	'ALA'(2,.43%),'AST'(2,.43%),'ATK'(2,.43%),'DPS'(2,.43%),'FPT'(2,.43%),'2,'HPI'(2,.43%),'HPS'(3,.64%),'KVR'(2,0.43%),'LPF'(2,.43%),'LPP'(2,.43%),'LRP'(2,.43%),'PAV'(2,.43%), 'PHL'(2,.43%),'PLP'(2,.43%),'PSL'(3,.64),
4-mer	'PSLK' (2, 53%) **(SEQ ID NO:150)**

Sequence analysis of DNA of a set of selected phage particles indicate that the method allowed identification of a consensus amino acid sequence, which was then validated against the most frequent pattern identified by the algorithm. The algorithm identified the following consensus sequences:

Constrained consensus: "P/S, S, T, P/S/T, P, P, S"

Non-constrained consensus S, P, L, L/T, S, A/N/P/T/V, P

The pattern-recognition algorithm disclosed herein is applicable to pattern recognition in any amino acid sequence and does not require an initial query sequence,

unlike prior art methods. These pattern recognition techniques can be used to identify any pattern in amino acid sequences, as exemplified herein.

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We claim

1. A substantially purified polypeptide comprising an amino acid sequence according to formula 1:

B1-[X1-S-T-X2-P-P-S]-B2;

wherein X1 is selected from the group consisting of P and S; and

X2 is selected from the group consisting of P, S, and T; and

wherein B1 and B2 are independently 1-5 amino acid residues, or are absent.

2. A substantially purified polypeptide comprising an amino acid sequence according to formula 2:

B1-[S-P-L-X1-S-X2-P]-B2;

wherein X1 is selected from the group consisting of L, T, and S; and

X2 is selected from the group consisting of A, N, P, T, and V; and

wherein B1 and B2 are independently 1-5 amino acid residues, or are absent.

3 In a third aspect, the present invention provides a polypeptide comprising an amino acid sequence of a polypeptide according to formula 3:

B1-[X1]-B2;

wherein X1 is a polypeptide selected from the group consisting of **SEQ ID NOS:1-149**; and

wherein B1 and B2 are independently 1-5 amino acid residues, or are absent.

4. A substantially purified compound that competes with one or more of the polypeptides according to **SEQ ID NOS:1-149** for binding to a GalNAc-specific binding protein.

5. A pharmaceutical composition comprising the substantially purified polypeptide of any one of claims 1-14 and a pharmaceutically acceptable carrier.

6. A substantially purified nucleic acid composition comprising a nucleic acid sequence that encodes a polypeptide according to any one of claims 1-4.

7. A recombinant expression vector comprising the substantially purified nucleic acid sequence of claim 6.

8. A recombinant host cell transfected with the recombinant expression vector of claim 7.

9. A method for stimulating immune system activity in a subject, comprising administering to a subject an amount effective of a polypeptide according to any one of claim 1-4, or a pharmaceutical composition according to claim 5, for stimulating immune system activity.

10. The method of claim 9 wherein the subject is suffering from an infection.

11. The method of claim 9 wherein the subject has a tumor.

12. The method of claim 9 wherein the subject has a bone disorder.

13. The method of claim 9 wherein the subject is in need of anti-angiogenic therapy.

14. The method of claim 9 wherein the subject is suffering from an immune suppressed disorder.

15. The method of claim 9 wherein the subject is suffering from pain.

16. The method of claim 9 wherein the subject is also receiving a vaccination.

17. A method for treating an infection in a subject, comprising administering to a subject with an infection an amount effective of a polypeptide according to any one of claim 1-4, or a pharmaceutical composition according to claim 5, for treating the infection.

18. A method for treating a tumor in a subject, comprising administering to a subject with a tumor an amount effective of a polypeptide according to any one of claim 1-4, or a pharmaceutical composition according to claim 5, for treating the tumor.

19. A method for treating a bone disorder in a subject, comprising administering to a subject with a bone disorder an amount effective of a polypeptide according to any one of claim 1-4, or a pharmaceutical composition according to claim 5, for treating the bone disorder.

20. A method for anti-angiogenic therapy in a subject, comprising administering to a subject in need thereof an amount effective of a polypeptide according to any one of claim 1-4, or a pharmaceutical composition according to claim 5, for inhibiting angiogenesis.

21. A method for treating an immune suppressed disorder in a subject, comprising administering to a subject with an immune suppressed disorder an amount effective of a polypeptide according to any one of claim 1-4, or a pharmaceutical composition according to claim 5, for treating the an immune suppressed disorder.

22. A method for treating pain in a subject, comprising administering to a subject in pain an amount effective of a polypeptide according to any one of claim 1-4, or a pharmaceutical composition according to claim 5, for treating the pain.

23. An improved method of vaccination in a subject, comprising administering to a subject receiving a vaccination an amount effective of a polypeptide according to any one of claim 1-4, or a pharmaceutical composition according to claim 5, for promoting an improved immune system response to the vaccination.

24. A method for identifying a GalNAc mimetic compound, comprising:

a) contacting a plurality of test compounds with a GalNAc-specific lectin under conditions to promote binding of the GalNAc-specific lectin with a GalNAc mimetic compound;

b) removing unbound test compounds;

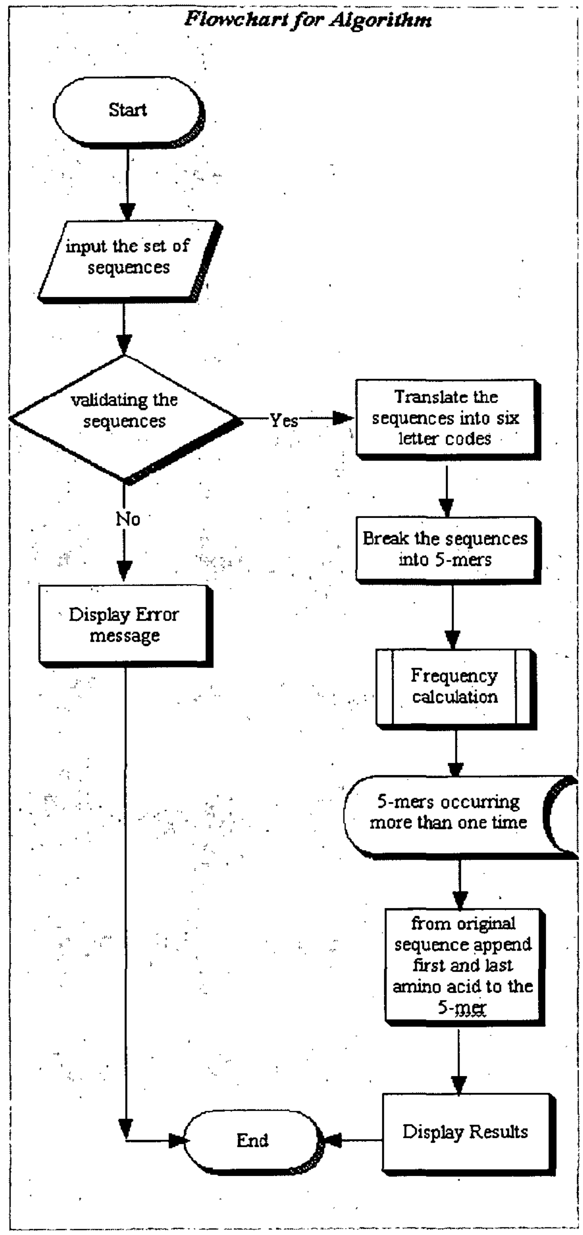
c) repeating steps (a) and (b) a desired number of times;

d) contacting test compounds bound to the GalNAc-specific lectin with an amount effective of a polypeptide comprising or consisting of an amino acid sequence according to **SEQ ID NOS:1-149** to displace the bound test compounds if the bound test compounds are acting as GalNAc-mimetics; and

e) identifying those test compounds that are displaced from the GalNAc-specific lectin by a polypeptide comprising or consisting of an amino acid sequence according to **SEQ ID NOS:1-149**, wherein such test compounds are GalNAc mimetic compounds.

25. The method of claim 24 wherein the test compounds comprise polypeptides.

26. The method of claim 24 further comprising synthesizing the GalNAc mimetic compounds.


Flowchart for Algorithm
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validating the sequences
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No
Translate the sequences into six letter codes
Break the sequences into 5-mers
Frequency calculation
5-mers occurring more than one time
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Display Results
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Figure 1

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